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MICROGRAVITY EFFECTS ON STANDARDIZED COGNITIVE PERFORMANCE MEASURES

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ABSTRACT

The purpose of this experiment, selected to fly on International Microgravity Laboratory (IML-2) spacelab mission, is to determine the effects of microgravity upon cognitive skills which are critical to successful performance of many tasks on board the space shuttle. Six tests from the Unified Tri-service Cognitive Performance Assessment Battery (UTC-PAB) will be administered to the Mission Specialists to fulfill the goals of this experiment. These tests are based upon current theoretical models of human performance, and the hypothesized effects of microgravity. The principal objective is the identification of the effects of microgravity upon specific information processing skills affecting performance from those of fatigue and shifts in work/rest cycles. Multiple measures of both short- and long-term fatigue will be obtained and used as a major independent variable for the analysis of these performance data. Scientific supporting studies entitled "Training schedules to acquire and maintain performance stability" will determine optimum practice and performance testing schedules for the astronauts. The same tests will be used post-flight to collect data on the recovery of any cognitive performance impairment compared to pre-flight, baseline levels.

BACKGROUND

Problem

Astronauts are subject to a variety of stresses during space flight. These stresses include microgravity, physical isolation, confinement, lack of privacy, fatigue, and changing work/rest cycles (Christensen & Talbot, 1986). Any one or a combination of these stressors could degrade the cognitive skills required to perform tasks essential to the success of the mission. Of these potential stressors, the effects of fatigue and of the changing work/rest cycle are known to cause deteriorations in astronaut productivity (Stepanova, 1975).

Purpose

The purpose of the inflight research is to determine the effects of microgravity on cognitive skills required by

many tasks on board the space shuttle. This paper describes; (1) the performance tests and the rationale for selection, (2) the pre/post baseline and inflight experiment, (3) the supporting ground-based studies that will determine the reliability and stability of the measures, and (4) the controls necessary to differentiate the effects of fatigue and changing work/rest cycles from microgravity.

Previous Research

To date, no systematic attempt has been made to determine the effects of space flight on cognitive skills. Despite the lack of systematic observation, anecdotes and documented instances of degraded performance do exist (Covault, 1988). Additionally, two experiments have examined performance in space. The first (Ross, Schwartz, & Emmerson, 1987) demonstrated a deterioration in mass discrimination during flight, which persisted for approximately 3 days after touchdown. The authors did not pinpoint the source of the deterioration although some aspects of judgment and psychomotor coordination were implicated. The second (Ratino, Repperger, Goodyear, Potor, & Rodriguez, 1988), examined the simple reaction time, choice reaction time, and time perceptions before, during, and after a mission. The simple and choice reaction time tasks showed no effects of space flight. The time perception task showed an increasing deterioration in estimates of short durations (2 to 16 s) throughout the mission. Again, the locus of the deterioration was not identified.

It is anticipated that our experiment will benefit from having the results from the IML-1 space flight experiment, Mental Workload and Performance Evaluation (MWPE) scheduled to fly approximately two years before IML-2. The MWPE experiment will evaluate the most effective human computer interface while astronauts perform a "Fittsberg" task (Hartzell, Gopher, Hart, Lee, & Dunbar 1983). The task will simultaneously measure the accuracy and reaction time of retrieving items from short term memory and skilled motor coordination response times while using three different types of input/output controllers; joystick, keyboard, and trackball. The

differential effects of microgravity on the output stage of human information processing will be particularly beneficial to our study since it will use the same hardware system available to us at the Performance Assessment Workstation (PAWS) on board the space shuttle. Even though additional measures of subjective workload and mood state will be taken from the Mission Specialists during the MWPE, IML-1 flight, the primary objective of the "Fittsberg" task will yield psychomotor response times to evaluate human engineering issues (Newman & Bussolari, 1990).

The "Fittsberg" task combines the more common Serial Memory Search Task (Sternberg, 1969) and the historical discrete motor movement Fitts Task (Fitts & Peterson, 1964). Even though the task combination was designed for another purpose, it is important to realize that if generalizations or predictions are to be made of astronaut performance from one space flight mission to another, with varying task demands and durations; then consideration should be given to standardizing the testing procedures and using more common transportable system software. These factors will become increasingly important when large performance databases must be shared to accomplish future international space flights. Therefore, due to the scarcity of reported cognitive performance data, it is mandatory that additional well controlled, cognitive studies using "standardized" procedural testing, be conducted before long term space flights are flown. This paper outlines the origin of such a performance test development program by the military that is relevant to NASA operations.

Human Performance Testing in Military Medical Research

For many years military medical researchers have recognized that the development of microcomputer-based tests of human performance would have broad applicability. The resulting test systems employed a variety of tests, batteries, and hardware, all purporting to measure such functions as memory, information processing abilities, logical reasoning, tracking, etc. (Bittner, Carter, Kennedy, Harbeson, & Krause 1984; Shingledecker, 1984; Thorne, Gensen, Sing, & Hegge 1985). While these test systems were suitable for answering isolated questions; standardization of procedures, software language, and hardware was lacking, making comparison of results from different laboratories difficult. Several years ago, in response to the challenge of evaluating the side effects of chemical defense pretreatment and antidote drugs on human performance, the U.S. Army Medical Research and Development Command formed the Joint Working group for Drug Dependent Degradation of Military Performance (JWGD3 MILPERF). This tri-service working group was broadly tasked with the mission of developing standardized methodologies for the assessment of human performance.

The UTC-PAB

One of the principal products of the JWGD3 effort has been the Unified Tri-Service Cognitive Performance Assessment Battery (UTC-PAB), a set of 25 standardized human performance tests which run on a microcomputer (Englund et al., 1987; Hegge et al., 1985; Perez et al., 1987; Reeves et al., 1989). The tests comprising the UTC-PAB were selected after an exhaustive search of the human performance literature and in-depth interviews with the original test authors. A team of experienced human performance investigators evaluated the candidate tests for validity, reliability, and sensitivity to provide investigators and practitioners with the means to sample a broad range of human performance functions. The prototype "beta testing" phase of the UTC-PAB has been completed. It includes a detailed set of hardware-independent specifications, as well as an authoring system to construct additional prototype tests for concept formation. The original 25 tests run on IBM-compatible microcomputers using the system clock, standard system keyboard, and a serial port joystick for tracking tests. This NASA project will implement several of the tests, discussed later in this paper, on a NASA supplied GRID 1530 computer. Additional implementations of the UTC-PAB tests in a variety of forms are currently under way, including a version of the tests for clinical neuropsychologic screening that will run on several laptop computers. All of these activities are being coordinated by the Office of Military Performance Assessment Technology (OMPAT) located at the Walter Reed Army Institute of Research (WRAIR) in Washington, DC, which assumed the functions of the JWGD3 in August 1989. The founder of the triservice JWGD3 and the current Director of OMPAT is Dr. Fred Hegge.

The UTC-PAB has become recognized worldwide as a standard for military performance testing. The AGARD NATO (Working Group 12) has recently published the test specifications of a subset of the UTC-PAB tests for research with environmental stressors (AGARD, 1989). The STRES battery is an example of a product of international standardization coordinated by OMPAT. The tests were selected by NATO, specified by the Air Force, and programmed by the Navy. Through this cooperative effort the OMPAT is continuing the process of establishing a mechanism for collecting the data from numerous international studies using a subset of the UTC-PAB. The existing data base at OMPAT has grown into a central Performance Information Management System (PIMS) located at WRAIR in Washington, D.C. This networked data base will enable the establishment of international performance norms for the UTC-PAB tests, as well as document the effects of a wide variety of environmental stressors and drugs on human performance. Free access to the PIMS data base and performance measurement tools is granted by the Director, OMPAT at a toll-free, bulletin board number 1-800-542-7844.

GENERAL APPROACH

In order to capitalize on the standardization already achieved in performance testing by the Department of Defense and NATO, the Life Sciences Division at NASA Headquarters competitively selected a team of researchers responding to a NASA Headquarters research announcement. A portion of this announcement was initiated by Dr. Janis Stoklosa, Chief, Human Factors, Behavior, and Performance, to study the effects of microgravity on astronaut performance on IML-2. The team is headed by the author of this paper, the Principal Investigator, Dr. Samuel Schifflett. The government co-investigator is Dr. Jonathan French, from the Sustained Operations Branch of the Armstrong Laboratory Brooks AFB, Texas (formerly the Crew Performance Function of the USAF School of Aerospace Medicine). Other participating co-investigators are Dr. Douglas Eddy, NTI, Inc. and Dr. Diane Damos, University of Southern California.

Six tests from the UTC-PAB were selected by the team, based on current theoretical models of human performance and on the hypothesized effects of microgravity. These tests will be further studied in ground-based environments to determine required parameters for use in space. Final parameters will be incorporated into software that will run on the specified Space Shuttle hardware, and within the allowed time constraints.

The actual experiment to be performed in space will involve testing each Mission Specialist for 20 minutes a day using behavioral and subjective tests selected to evaluative cognitive functioning while in orbit. Particular emphasis will be given to the question of fatigue. Multiple measures of both short- and long-term fatigue will be obtained and used as a major independent variable in analyzing the performance data.

RATIONALE FOR SELECTING TESTS

Several factors must be considered in selecting tests for use on board the space shuttle. One of the most important of these is the restrictive time available during flight for performance assessment. Another constraining factor is the prohibitive cost of developing flight worthy hardware not previously furnished by NASA. A critical factor to consider is the specific information processing skills necessary to the success of the mission. The final issue that is the most relevant to this experiment, is the information provided by a specific test should aid in identifying the cognitive processes or information processing stages affected by microgravity. These four factors were taken into account in selecting the six tests included in the performance assessment battery.

Many different cognitive skills are critical to the successful completion of tasks on board the shuttle. Upon examination of past Mission Specialist's tasks and insight gained at a recent NASA workshop held at JSC on Human Factors requirements, and from conferences

such as this one; a list of functional task areas were identified to be potentially affected by microgravity. Of these functions, spatial information processing, tracking, and time-sharing play a disproportionately important role in the success of a variety of Spacelab and Spacestation tasks. For this reason, a tracking test, a spatial information-processing test, a time-sharing test, and a directed attention switching test have been included in the battery. Two other tests, the Sternberg Memory Search test and the Continuous Memory test, have been included because each of these examines specific cognitive processes and stages of information processing. Thus, the locus of microgravity effects, if any, on cognitive functioning can be identified relatively clearly. A description and rationale for each test is given below. Detailed descriptions and procedures may be found in Perez et al. (1987) for all the tests and combinations except the Matrix test and the Manikin-Mathematical Processing combination. Simple and choice reaction time tasks were not included in the proposed battery even though they have reliable and short training times because Ratino et al. (1988) failed to identify any performance deterioration during space flight.

NASA PERFORMANCE ASSESSMENT BATTERY (PAB)

After careful review of the statistical properties of each test and examining theoretical rationale of the UTC-PAB, the following performance tests were selected for use in this experiment.

Tracking. One of the primary potential effects of microgravity is a disruption of visual-motor coordination due to disturbances in the sensory input and motor output channels. To probe for this effect, a tracking test will be used. One of the candidate tracking algorithms is the Crossover Model developed by McRuer and Jex, (1967) and validated by DOD, NASA, FAA in numerous studies. It requires the subject to maintain a target in the center of a horizontal line. A fixed difficulty (λ level) is used to displace the target, and the subject must manipulate a control device to null this input disturbance. Even though, it has limitations on its approach (frequency domain), two characteristics recommend it for inclusion in the proposed battery. First, performance reaches differential stability in 150 brief trials (Damos, et al., 1984). Second, it is known to be affected by a variety of exotic environments, including alcohol (Klein & Jex, 1975; Dott & McKelvy, 1977), hypoxia (Nesthus, Schifflett, Bomar & Holden, 1988), fatigue (Gevins, Cutillo, Fowler-White, Illes, & Bressier 1988).

However, in the present experiment, several tracking algorithms must be evaluated prior to specifying the tracking test's final configuration. Some of these issues related to pilot workload and dynamics have been addressed in a conference sponsored by the Air Force (Frazier & Crombie, 1982). Alternate models will be considered such as the Optimal Control Model (Levison, Barron, & Kleinman, 1969) that is a time-domain

approach to establishing operator describing functions. Alternate tracking algorithms will be evaluated prior to the ground-based support experiments described in a later section of this paper. However, the tracking task will be presented at a difficulty level empirically derived for each Mission Specialist slightly below the maximum resource capacity, i.e. subcritical mode, if the Unstable Tracking task is used. A compensatory tracking task may be more diagnostic to subtle changes in psychomotor processing (Wickens, 1986).

Matrix Rotation Task. The functional de-afferentation of the otolith organs that occurs in space, along with associated effects on the visual and cerebellar systems, raise serious questions about the individual's spatial processes. Thus, it is desirable to probe for subtle effects on the person's ability to perceive, remember, and process spatial information. The Matrix Rotation task developed by Phillips, (1974) and Damos & Lyall, (1984) will be used to evaluate the effects of microgravity on spatial processing. The Matrix Rotation Task should not be confused with the task implemented by Thorne, et al. 1985 or the commonly used Match-to-Sample task reported by Thomas & Schrot, (1988) at the Naval Aviation Medical Institute. This test uses 100 basic patterns. Each pattern is a 5 by 5 matrix with five illuminated cells that have been selected at random. At the beginning of the trial, the subject sees a pattern. After the subject studies the pattern, he presses a response key. The pattern is immediately erased and a new one presented. The subject must decide as quickly as possible if the new pattern is identical to the preceding pattern. The subject then presses one key for "same" or another key for "different." As soon as the response is made, a third pattern appears. The subject must now compare the new pattern to the immediately preceding pattern, etc. For "same" responses, the two patterns are never presented in exactly the same orientation; the second pattern is always rotated either 90 degrees to the left or 90 degrees to the right relative to the preceding pattern. Both correct reaction time and percentage correct are used as dependent measures.

Although no data were located in the open literature which examined the effects of exotic environments on this test, it does have two advantages. First, performance on this test reaches differential stability in approximately 15 minutes. Thus, little practice is required. Second, concurrent verbal suppression tasks have been shown not to affect performance on the Matrix task, indicating that this task indeed measures some aspect of spatial information processing. Studies examining the effect of fatigue and changes in the sleep rest cycle using this task are under development by the military.

Sternberg Memory Search. The general Sternberg paradigm requires subjects to respond as rapidly and accurately as possible to visually presented letters. At the beginning of the test a set of letters drawn randomly from the alphabet are presented to the subject for

memorization. The set of letters (positive set) stay on the screen for 10 seconds, then the screen is cleared and a series of single test letters are presented. If the presented letter matches one of the letters in the previously memorized positive set, the subject responds "same" (key press). If a different letter appears (negative set), then the subject responds "different" (key press) indicating a non-matching letter was presented.

Some questions have been raised about the reliability of the intercept and slope scores derived from the mean reaction time of multiple size memory sets (Carter, Krause, & Harbeson, 1986). Reliability is a concern if the fixed set procedure for presenting the stimuli is used for a large number of trials (Wickens, Vidulich, Sandry, & Schifflett 1981). In this procedure, an item that has been designated as a target in one trial can never be used as a distractor (non-target) in subsequent trials. Thus every time a target stimulus is presented, the subject should respond. This presentation procedure results in a gradually decreasing slope that, with a high number of trials and sufficient practice, will be statistically indistinguishable from zero. The Sternberg task included in this version of the UTC-PAB uses a set size of four letters that are changed after each block of trials. Thus, a letter can be a target in one session and a distractor on another. Carter, et al. (1986) found that a variable four letter memory set represents the more cognitive aspects of information processing, is both reliable and stable, and is highly correlated with the other letter set sizes (1,2, or 3). This will be particularly helpful in evaluating the microgravity effects on the cognitive comparative processing stage. Using a single set size of four letters will save time and provide data on the locus of subtle deleterious effects of the microgravity environment on performance.

Continuous Recognition. One critical aspect of higher cognitive function is the ability to maintain attention and to carry out repetitive cognitive processes over some period of time. In many ways, such activities encompass those which were traditionally referred to as "vigilance." However, they add the dimension of active processing of information, rather than simple monitoring. One task that appears to capture the performance elements above is the Continuous Recognition Test (Hunter, 1975; Shingledecker, 1984). In this the subject sees two numbers, one above the other. The task is to remember the bottom number. When the next two numbers appear, the task is to determine if the new top number is the same as the previous bottom number. However, before responding, one must note the new bottom number because as soon as a response is made, the numbers are replaced by a new pair. Thus, the subject must not only exercise very short-term memory, but more importantly, must inhibit the response until the new bottom number is committed to memory. The appropriate strategy is to develop a set pattern of observing, memorizing, observing, comparing, and responding. This sequence is different enough from that

required by most routine tasks that it requires constant attention allocation. Even brief lapses result in errors. The task can be made even more difficult by requiring the subject to remember and respond to numbers further removed from the immediately preceding one (e.g., two- or even three-back), thus imposing a much higher load on immediate memory.

This task has not been used as often as others in the UTC-PAB battery. However, it has a respectable data base indicating that it is a sensitive test of both short-term memory and attention allocation (Perez et al., 1987). It provides a large number of data points in a short period of time, and has good test-retest reliability.

Prior to the inflight experiment, it will be necessary to develop additional data on the parameters that will optimize the value of the data collected in space. This will be done in the context of the preliminary studies described in other sections of this paper. We will determine, for instance, the optimum amount of practice required for stability, as well as the value of using the one-, two-, or three-back condition. The continuous recognition test is known to be sensitive to g-stress (Ross & Chambers, 1967) and to alcohol (Carpenter & Ross, 1965).

Dual Tasking--Tracking and Sternberg Memory Search. One of the most critical and potentially sensitive higher cognitive functions that might be affected by microgravity is the ability of the subject to allocate attentional resources among several tasks. To investigate this, the present study will use the time-sharing paradigm that has been well studied in cognitive psychology (Damos & Wickens, 1980; O'Donnell & Eggemeier, 1986; Damos, 1991). The specific form of this paradigm will be the dual task included in the UTC-PAB. This consists of the Sternberg task and the Tracking task being presented simultaneously. In this implementation of the Dual Task, the tracking task is presented in the middle of the screen and the letters of the Sternberg task appear in a fixed location directly above the center null point. The target of the compensatory tracking task moves laterally. One memory set will be used, consisting of 4 letters. Due to the nature of the dual task, the "fixed set" procedure must be used, in which the same memory set letters are presented with several probe letters for each daily session. For a recent study discussing the implementation of the dual task when investigating the effects of antihistamines on military weapon system controllers see Nesthus, et al. 1991).

Performance Switching Task--Manikin and Mathematical Processing. Time-sharing, as explained above in the Dual task, is different from another required attentional process that could be affected by microgravity. Astronauts must make rapid shifts in the attentional focus, as well as in the skills required to respond to a change in task demands. This externally-directed behavior defies automaticity in any true sense, since it must be flexible

enough to respond to unusual demands. Thus, a test is needed to probe the subject's ability to shift attention and resource allocation in response to rapidly changing and unpredictable external demands. Such a procedure has been created that uses two tasks currently in the UTC-PAB.

In this procedure, the subject has two distinct and discrete tasks to perform. One is a spatially-based task, and the other is a mathematically-based task. Each of these appear, trial by trial, simultaneously on the screen. However, an arrow appears at the same time directing the subject which task is "active" (i.e., must be responded to). The subject must make an exclusive response to the active task, where reaction time and percent-correct data are obtained only for that task. The switching from task to task for each trial is random (within constraints). Therefore, the subject must remember to watch the arrow on each trial, allocate the appropriate resources to respond to that trial, and then make the appropriate response. This paradigm provides a test of the attention switching skills described above.

The two tests selected to exercise this paradigm are the Manikin test and the Mathematical Processing test. The Manikin test has a long history of use (Benson & Gedy, 1963; Reader, Benel, & Rahe, 1981;) and is presented in a wide variety of formats by military psychologists (Miller, Takamoto, Bartel, & Brown, 1985). As implemented in this microgravity experiment, a manikin "stick figure" is presented facing either forward or backward. In addition, the figure can be either upright or upside-down. The figure is also standing on a box and inside the box is either a rectangle or a circle. In the figure's two hands are a rectangle and a circle. The subject's task is to note which symbol is inside the box, and then to determine which of the manikin's hands is holding the designated symbol. The subject then presses the left or right of two keys corresponding to the manikin's left or right hand.

Exposing the Mission Specialists to a series of manikins presented in a variety of orientations in microgravity where the astronaut has the freedom to position his own body during work and sleep in non-traditional gravity orientations; will be one of the more theoretical interesting tests of spatial processing using a human form. The effects of microgravity on whole body orientation will give insight into whether this test is a perceptual measure of spatial transformation of mental images or involves pure spatial abilities requiring readaptation (Carter & Wolstad, 1985).

The Mathematical Processing test is based on similar tasks described by Perez et al. (1987). It presents two single-digit numbers that must be added or subtracted. If the answer is greater than 5, one response is given. If the answer is less than 5, another response is required. This task has been reported by Shingledecker

(1984) to be a relatively pure index of mathematical functioning.

METHODS/TECHNIQUES

The software for the NASA Performance Assessment Battery (PAB) is being programmed and delivered under the oversight of Dr Samuel Moise, NTI, Inc. in collaboration with Ms Kathryn Winter, Naval Aerospace Medical Research Laboratory. The software team is following a software verification plan that has been mutually agreed upon by NASA and the Air Force. The software will be in executable form, on 3.5" floppy disk, compatible with the GRID 1530 microcomputer and the attached controller devices; joystick or trackball. The programs will reside on the hard disk prior to flight and be backed-up with system disks and individual data storage disks for rapid loading during flight, if required. Provision for entering the final values on the tracking task for each astronaut will be made available if late access (Launch -3 days) is granted.

All system integrity checks and the initial transfer of the programs to the GRID hard disk are automatically performed by software provided by the Air Force. Start-up of the test system requires only a single command typed by the Mission Specialist at the GRID's keyboard. The six performance tests, a subjective fatigue scale, and a mood questionnaire will be sequenced by a control program that will automatically present all tests once started.

Data from all tests will be stored on disk in a format compatible with the UTC-PAB normative data base. It is estimated that the data will occupy approximately 35K of disk space per Mission Specialist per day. For the entire 13 day mission, this would be a total of 1.61 megabytes for all the raw data to be collected by these tests. This is well within the storage capacity of the on-board computer system. As a back-up, the data will also be stored in summary statistical format on each individual 3.5 inch data disk. The data files will be formatted using the UTC-PAB and NATO standards for data processing by commonly used statistical software packages.

RESEARCH PLAN

Phase I Ground-Based Scientific Support Studies

The primary purpose of the first series of ground-based scientific support studies is to obtain three types of data related to reliability, training, and normative database. The first type provides basic information about the trial-to-trial reliability of the tests and the amount of practice necessary to reach differential stability. The second type will provide data on the most efficient training scheme. These data are necessary to ensure that all Mission Specialists are completely trained before launch. The third type will provide a normative data base on all of the tests. This data base will be collected on approximately

100 subjects with the appropriate range of age and male/female representation. This first series of studies will only be conducted after the test battery has been tested on the final NASA Grid computer configuration. Dr Diane Damos, Co-investigator, University of California will be responsible for all aspects of the study while using the coordinated technical expertise of the USAF Sustained Operations Branch staff and contractors from NTI, Inc. These data will supplement the large existing UTC-PAB data base that exists for most of these tests.

A control study, sponsored by the Air Force, will be conducted in the sustained operations laboratory to demonstrate the sensitivity of the tests to fatigue. The performance battery will be identical to the one used in the test reliability and stability study. Approximately eight to twelve subjects will be selected as closely as possible from the same general population as the mission specialists. Each subject will be tested under both rested and fatigued conditions separated by at least one week. Order of testing will be counterbalanced. Several physiological and biochemical covariate measures will be taken (Brainard, Hannon, French, & Storm 1990; Brainard, Rollag, Hannon, French, & Storm 1990).

Fatigue has been manipulated in several ways within the sustained operations laboratory (French, Hannon, & Brainard, 1989; Morris, 1984). To demonstrate the sensitivity of the proposed battery to fatigue, sleep deprivation will be manipulated. The SAM Fatigue scale, the Sleep Quality Inventory, and the Mood Scale which have demonstrated sensitivity to fatigue in a wide variety of research and long-term field studies will be used to supplement the performance test results (Storm, Dowd, & Boll, 1990).

Phase II Flight Experiment

The Phase II flight experiment will test several hypotheses relating to the interactive effects of microgravity, work/rest shifts, and resulting fatigue on cognitive performance. All the hypotheses will be tested against the null hypothesis that there is no difference among the groups, nor across days. Each test- and scale-dependent measure will be evaluated separately.

The IML-2 flight will consist of two work/rest cycles shifted by 12 hours. A typical shift schedule is shown in Figure 1. It is expected that two of the Mission Specialists assigned to Shift A will gradually be time adjusted forward 12 hours prior to flight over a period of several days. This Shifted Group will go to sleep after a few hours in orbit when the Non-Shifted Group (two other Mission Specialists) assigned to Shift B will complete their duty day.

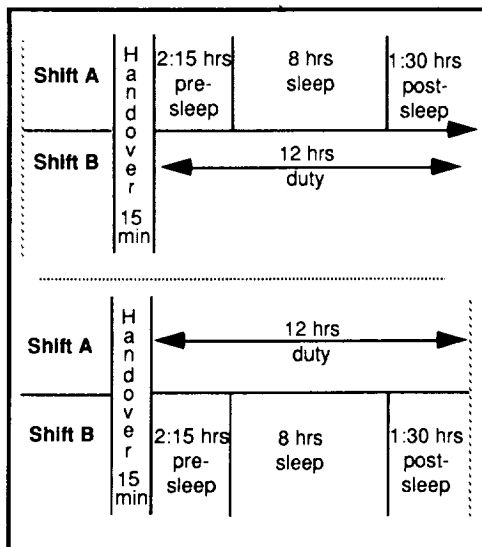


Figure 1. Typical Two-Shift On-Orbit Work/Rest Cycle

The two major independent group variables include microgravity and the effects of ground phase shifting. The groups will be as follows:

GROUP	PRE-BASELINE	FLIGHT	POST-BASELINE
	-LI8 to -L3	MD1 to MD13	+R1 to +R16
Non-phase shifted	*0800-2000	0800-2000	0800-2000
Phase shifted	partial	2000-0800	0800-2000

*assume 0800 Launch L=Pre-Launch MD=Mission R=Recovery Day

TABLE 1 - PERIODS OF DATA ACQUISITION FOR EACH GROUP

General Hypotheses

1. Performance will deteriorate across days as the result of time in microgravity relative to the preflight baseline for both groups. Cumulative fatigue will increase concurrently.
2. Performance will deteriorate more across the first 3-5 days for the phase shifted groups relative to the non shifted groups. Fatigue will increase, then decrease in a similar manner.

Specific cognitive skills affected by microgravity will be indicated by the specific tests effected. For example, longer reaction times to the four item Sternberg Memory Search Test would indicate effects on central memory scanning processes.

The scores on tests and subjective scales during the preflight testing will provide a baseline for each subject. Difference scores for each subject will be derived by subtracting pre-flight baseline scores from flight scores.

Any residual effects of in orbit space flight will be evaluated using post-flight scores obtained in the recovery phase of the experiment. All hypotheses will be tested on the portional baseline difference scores using an analysis of variance statistical model. The 13 days of the inflight test will be a within group independent variable.

Phase III Post Flight - Mission Simulation Control Study.

Although the research team members believe that substantial insight into understanding the effects of microgravity and fatigue on performance can be gained using the proposed flight paradigm, serious consideration should be given to sponsoring a Phase III, Mission Simulation Control Study. This proposed study which is presently not funded by the Life Sciences Division of NASA is still at the planning stages. The data from a group of ground-based subjects performing tasks as similar as possible to those in space in the same sequence would provide the best comparison group for isolating the effects of microgravity from those of fatigue and circadian rhythms on performance. The drastic impact on performance data and fatigue ratings of a shuttle emergency or other unanticipated event can not be duplicated without such a post flight mission simulation control group. Mission related interruptions during sleep could be sufficient to cause Mission Specialists to experience fatigue that could deteriorate performance on a long mission such as IML-2.

If funded, the Mission Simulation Control Study would manipulate all the variables of the proposed flight study, except microgravity; including work/rest cycle shifts and simulated daily routine tasks involving exercise and housekeeping chores, e.g. meal preparation. The purpose of this study will be to demonstrate the sensitivity of the measures under conditions similar to the Phase II flight test. These data would serve as a comparison data set for the Phase II flight. The location of this study has not been determined but preliminary arrangements for mutual scientific exchange visits with Dr. Alex Gundel from DLR/DARA, Cologne, Germany has begun. Dr. Gundel has been identified by NASA as a participant to acquire data from the a IML-2 Life Sciences Experiment conducted by Dr. Timothy Monk, University of Pittsburgh entitled "Human Sleep, Circadian Rhythms, and Performance in Space". Dr. Gundel will use the sleep and circadian rhythm data from IML-2 to reconstruct, through computer simulation, a model of the IML-2 flight sleep cycles. If this proposed Mission Control Simulation Study is funded it will enhance the predictability of Dr. Gundel's computer simulation model by adding an extensive cognitive performance data set.

SUMMARY

The USAF Armstrong Laboratory, Crew Technology Division and the NASA Life Sciences Project Division have

combined their resources to assess the effects of microgravity on Mission Specialists. A subset of performance tests were selected from the Unified Tri-service Cognitive Performance Battery to be implemented on the International Microgravity Laboratory onboard the Space Shuttle. The flight experiment and supporting ground-based studies to determine the reliability and stability of the performance measures were explained. The paper concluded with a suggested control study necessary to differentiate the effects of fatigue and changing work/rest shift cycles from microgravity.

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